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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-101

*Test Operations Procedure 2-2-650
AD No.

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ENGINE COLD-STARTING AND WARM-UP TESTS

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1. SCOPE. This TOP provides procedures for evaluating the cold-starting capability of military engines with and without the aid of arctic-kit, engine heaters. Tests are usually conducted in conjunction with vehicle low-temperature tests (TOP's 2-2-816 and 2-2-708).

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

2.1.1 Chamber Climatic Tests. A temperature chamber for conditioning the vehicle and test heater to temperatures ranging from -18° to -51°C (0° to -60°F).

2.1.2 Outdoor Low-Temperature Tests.

A heated enclosure for preparing the vehicle for testing.

A heated enclosure to house instrumentation.

*This TOP supersedes TOP 2-2-650, 10 August 1978. A062736.

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2.2 Instrumentation.

<u>ITEM</u>	<u>MAXIMUM ERROR OF MEASUREMENT*</u>
Temperature sensors and recorder	±1.0°C (1.6°F)
Battery hydrometer	Specific gravity to ±0.005
Timer	±1 second
Voltmeter	±3% full scale
Ammeter and shunt	±3% full scale
Tachometer	±2 rpm (for cranking speed)
Pressure gages (as appropriate)	±1 psi
Oscillograph, or other device, to record voltages and current during cranking period	NA

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement out of 20.

3. PREPARATION FOR TEST.

3.1 Planning.

a. Prepare a test operations checklist using Appendix A as a guide and adding specifics for the test item and situation.

b. Design a data collection sheet to record such information as indicated in Paragraphs 3.5, 5.1.2, 5.2.2, and 5.3.2.

3.2 Vehicle.

a. Ensure that initial inspection and preliminary operation of the vehicle have been accomplished in accordance with TOP 2-2-505.

b. Prepare the test vehicle for cold-weather operation in accordance with the vehicle technical manual and FM 9-207 ^{1/} (e.g., arctic antifreeze installed in cooling systems and arctic lubricating and gear oils installed in other systems as prescribed in the lubrication order for cold-weather operation).

^{1/} FM 9-207, Operation and Maintenance of Ordnance Materiel in Cold Weather -18 to -54°C (0° to -65°F).

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c. Check that batteries are fully charged and have the correct specific gravity. Batteries are considered fully charged when the corrected specific gravity of the electrolyte is higher than 1.260. The range from 1.230 to 1.260 constitutes a three-quarter charge. (Note: Occasionally, a half-charged battery, 1.220 specific gravity, is used, when directed.) Deep cycle (discharge and fully charge) new batteries four times before using for this test.

3.3 Engine Heaters.

a. Inspect the heaters and other winterization kit components for equipment discrepancies, damage, or missing parts. If damage has been sustained, obtain authorization, and make repairs where possible.

b. Install the heater and other kit components on the vehicle in accordance with the instructions provided in the kit.

3.4 Temperature Chamber.

a. Position the vehicle in the test chamber so that:

(1) Air circulation is not impaired.

(2) Critical vehicle elements are accessible for inspection and operation.

(3) Clear and easy access is provided to personnel operation areas.

(4) Where possible, personnel can be seen through chamber observation windows.

b. Install ducts to remove vehicle and engine heater exhaust fumes from the chamber.

3.5 Data Requirements. Record the following:

a. Vehicle: Nomenclature; engine description; type and grade of fuel, lubricants, and other POL; personnel capacities.

b. Engine Heater: Type; manufacturer; serial number; technical description to include heating capacity (watts), external-power requirement, fuel consumption, method of operation (i.e., direct-fired-air or hot-water-heat source).

c. Instrumentation: Nomenclature; range and accuracy; calibration date; application and location.

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4. TEST CONTROLS.

a. Do not conduct tests when there is a change in chamber air temperature. If temperature changes more than +5°C (+9°F) during test, repeat the test.

b. Throughout testing, perform preventive (scheduled) maintenance as prescribed in the applicable technical manual; perform corrective (unscheduled) maintenance as required to keep the test vehicle and heater operational. Record RAM data in accordance with the latest guidance.

5. PERFORMANCE TESTS.

5.1 Cold Starting without Engine Heater. This test determines the temperature at which the vehicle can be started without external aids by repeating the procedure below at temperatures of -18° and -32°C (0° and -25°F), unless otherwise specified. Successful starts are obtained at the higher temperature before proceeding to the lower test temperature.

5.1.1 Method.

a. Cold soak the vehicle at the test temperature for a minimum of 8 hours after all components have stabilized to within 2°C (3.6°F) of the test temperature. When applicable, use cool-down blowers to facilitate equipment cold soaking. Use fully charged cold-soaked batteries for each cold-start attempt.

b. Make the first start attempt of the vehicle using the instructions in the technical manual. If not in adequate detail use the appropriate starting techniques in Appendix B for spark-ignition engines, in Appendix C for compression-ignition engines, or in Appendix D for turbine engines.

NOTE: A successful start is defined as a start of a cold-soaked vehicle with a continuous or total cranking period not to exceed 60 seconds (or as specified in the equipment operator's manual or applicable requirements document).

c. Make three first-start attempts with a fully charged battery at each test temperature unless two successful starts are obtained in succession. Two successful starts in three attempts constitute satisfactory performance. Whenever the engine starts, allow it to run for 15 to 20 minutes to reach normal operating temperatures. Should a start attempt be unsuccessful, start the vehicle by slaving, warming, or other appropriate means to purge unburned fuel. Repeat the starting attempt after sufficient soaking time is allowed to re-cool the engine.

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d. When required, following two successful starts at each temperature with a 100%-charged battery, attempt to start the engine with a 50%-charged battery in the manner described in paragraph 5.1.1c.

e. After engine start at -32°C (-25°F), evaluate personnel heater and defroster as outlined in TOP 2-2-708, if this is part of the test program.

5.1.2 Data Required.

a. Temperature of the following, as applicable:

(1) Test chamber.

(2) Engine coolant (for liquid-cooled engines).

(3) Cylinder head for air-cooled engines, and oil sump for turbine engines.

(4) Fuel.

(5) Engine oil sump.

(6) Battery electrolyte.

(7) Induction air.

(8) Transmission sump.

(9) Hydraulic oil reservoir.

(10) Battery box ambient.

(11) Starter.

b. Soak time.

c. Battery voltage and specific gravity before test, with percent of charge.

d. Time from starter engagement to first fire, to start, and to smooth operation.

e. Engine cranking speed.

f. Starter cranking voltage and current (oscillograph record).

g. Number of primer strokes to reach smooth operation.

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- h. Number of starting attempts.
- i. Fuel pressure.

5.2 Cold Starting with Engine Heater.

5.2.1 Method.

a. Cold soak the vehicle at -46°C (-50°F) to satisfy the cold (C2) condition of AR 70-38, unless otherwise specified. (The severe-cold (C3) condition of -51°C (-60°F) may also be required.) Soak the vehicle for at least 8 hours once all components are within 2°C (3.6°F) of the test temperature. When applicable, use cool-down blowers to facilitate equipment cold soaking.

b. Start the engine heater and monitor the engine oil (sump) and coolant temperatures. When the engine oil reaches the starting temperature specified in the test directive, or -32°C (-25°F) if not specified, turn off the heater and attempt to start the engine using the technique of paragraph 5.1.lb. If the engine fails to start, repeat the test increasing the preheat time in half-hour increments until the engine starts or 2 hours of preheat time is accumulated.

c. Once the preheat period has been determined, follow procedures of paragraph 5.1.lc, d, and e.

5.2.2 Data Required.

- a. Data as required in paragraph 5.1.2.
- b. Engine preheat time.

5.3 Engine-Heater Standby Test.

5.3.1 Method

a. Following a cold start at -51°C (or other required temperature), operate the engine until the temperature of the coolant (for liquid-cooled engines), the cylinder head (for air-cooled engines), or the oil temperature in sump (for turbine engines), stabilizes, and then shut down the engine.

- b. Start and operate the engine heater in the standby mode.
- c. Record the following every hour, and terminate standby operation when temperatures stabilize or after 24 hours.
 - (1) Temperature of coolant or cylinder head, oil sump, fuel, battery electrolyte, and battery box.
 - (2) Battery voltage.

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d. After turning off the heater, attempt to start the engine using the techniques of paragraph 5.1.1b.

5.3.2 Data Required.

- a. Standby operating time.
- b. Data recorded in paragraph 5.3.1c.

6. DATA REDUCTION AND PRESENTATION.

- a. Tabulate all data collected and compare the data with test criteria. Plot data against time, where applicable.
- b. Report all discrepancies by EPR.

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APPENDIX A
CHECKLIST GUIDE FOR ENGINE COLD-STARTING TESTS

ITEM	YES	NO	NA
<ol style="list-style-type: none">1. Preoperational inspection and services performed on vehicle.2. Vehicle prepared for cold-weather operation.3. Batteries fully charged.4. All required instrumentation calibrated, properly installed, and operational.5. Spare batteries on charge.6. Means available to slave-start engine if necessary.7. Required data recorded.8. Safety procedures posted and followed.9. Appropriate cold-weather clothing available for test personnel.			

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APPENDIX B
STARTING TECHNIQUES OF SPARK-IGNITION ENGINES

Starting techniques vary among different spark-ignition engine designs, and one of the primary objectives of the test may be to select the best method. When specified instructions are not stated in the test directive, the following technique may be employed for both carburetor and injection engines. This is based upon CRC designation E-15.

1. Air-Cooled Engine. To start air-cooled engines with the dry-manifold technique, hold the throttle from one-quarter to one-third open, place the transmission in neutral, and crank for up to 60 seconds. Prime during the cranking period and continue priming as needed until the engine runs smoothly at 1500 revolutions per minute without priming. Hold the booster control "on" until the engine runs unassisted.

If a start is not obtained with the dry-manifold procedure, the wet-manifold procedure must be used. Depending on engine displacement, pre-prime three to nine strokes. Wait for 30 seconds. With the throttle one-quarter to one-third open, and, with the transmission in neutral, engage the starter for no more than 60 seconds. Prime slowly when the starter is first engaged and increase as cranking progresses. Continue priming until the engine runs smoothly at 1500 revolutions per minute on carburetor-supplied fuel.

If the engine cannot be started using the wet-manifold procedure, examine the vehicle, engine, and engine accessories for structural or environmental failures. Correct all observed discrepancies. The engine should be started by towing (in the field), heating, or removing to a sheltered area, then operated at light load for 1 hour, and again prepared for cold soaking. Engines that start reliably at -32°C (-25°F) may be started below this temperature to determine, for information purposes, the startability limit without heating aids; care should be exercised, however, to ensure adequate lubrication with the heavy, cold, viscous lubricants. (Use procedure for liquid-cooled engines also.)

2. Liquid-Cooled Engines. In starting liquid-cooled engines with a dry manifold (preprime not used), close the choke fully, have the throttle one-quarter to one-third open, transmission in neutral, and clutch disengaged (if standard transmission). The engine should be cranked continuously for no more than 60 seconds to avoid overheating of the starter motor. Critical temperature of the starter must be monitored to prevent damage caused by overheating. After starting, manipulate the choke and throttle until smooth operation at 1000 revolutions per minute can be obtained.

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If a start is not obtained with the dry-manifold procedure, then with the choke three-quarters closed, throttle wide open, and clutch disengaged, prime the engine one to four strokes before engaging the starter. Wait approximately 60 seconds. Use primer, choke, and throttle to hold the engine speed constant.

The above provide typical guidelines; each engine has specific cold-starting procedures to be followed.

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APPENDIX C
STARTING TECHNIQUES OF COMPRESSION-IGNITION ENGINES

Use starting aids as required by temperature and engine displacement. Use of ether-like starting fuels is hazardous, and is avoided unless specifically indicated. Ratios of air-ether as high as 36:1 by volume are explosive. It is important that only the ether-priming equipment suggested by the engine manufacturer be used and in accordance with the instructions furnished.

With the vehicle transmission in neutral, the clutch disengaged (if a standard transmission), engage the starter. Injectors should be at full rack in all cold starting as specified by the engine manufacturer. To avoid starter overheating, the cranking period should not exceed 60 seconds unless thermocouples measure temperature, and the maximum, acceptable temperature is known. Preheat or prime slowly while cranking. Fuel pressure should be readable as soon as cranking is started; if not, discontinue the starting attempt, and determine the cause. If a start is not obtained, wait at least 2 minutes before starting the second attempt. During the waiting period fresh electrolyte can come into contact with the battery plates, providing more electrical energy for the second attempt than would otherwise be available.

Except for prepriming, continue as above until the engine runs on primary fuel. Use a manifold or airbox heat or priming fuels as necessary to keep the engine running smoothly after starting. Check lubricant and fuel-oil pressure while running. As soon as the engine is running smoothly without aids, reduce to 1200 to 1500 rpm for warmup. Note any unusual results, such as unburned primary fuel in exhaust, detonation, or excessive smoking.

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APPENDIX D
STARTING TECHNIQUES FOR TURBINE ENGINES

Starting techniques vary among different turbine engines. Most, however, employ an automatic starting sequence that is electronically controlled. The appropriate operator's manual or technical manual must be followed during the starting sequence. Operating personnel must be knowledgeable of the hardware characteristics of the item being tested.

With the vehicle transmission in neutral, initiate the starting sequence. Monitor appropriate gages; voltage, pressures (fuel, oil, etc.), during and after the start attempt. To avoid possible damage to the starter, total continuous cranking time should not exceed 60 seconds, unless the system specification or operator's manual allows a greater cranking period. If a start is not successful, follow procedures necessary to prepare engine for next attempt (this may involve an override procedure to purge the engine of unburned fuel after the second or third unsuccessful start attempt).

Once a start is made, continue operating until all components are at their normal operating temperatures. Continue monitoring all fuel and oil pressures and temperatures during the running cycle. Note any unusual results.